First observations of a foreshock bubble: Implications for global magnetospheric dynamics and particle acceleration

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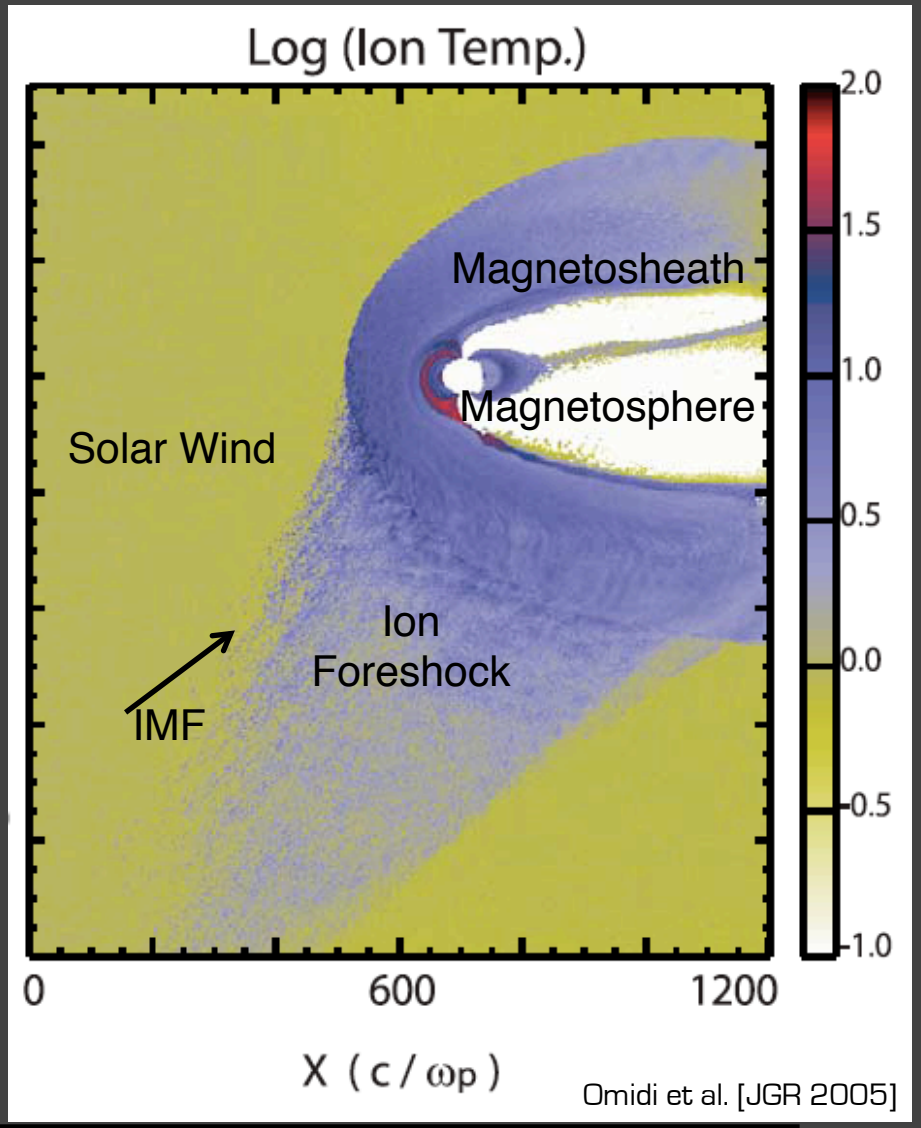
Earth's Foreshock Region

- Quasi-parallel shock region
- Characterized by suprathermal ions back-streaming from the bow shock
- Significant plasma instability and waves in this region
- Magnetopause disturbances can result from:
  - Hot flow anomalies (HFAs)
  - Foreshock cavities
  - Foreshock bubbles

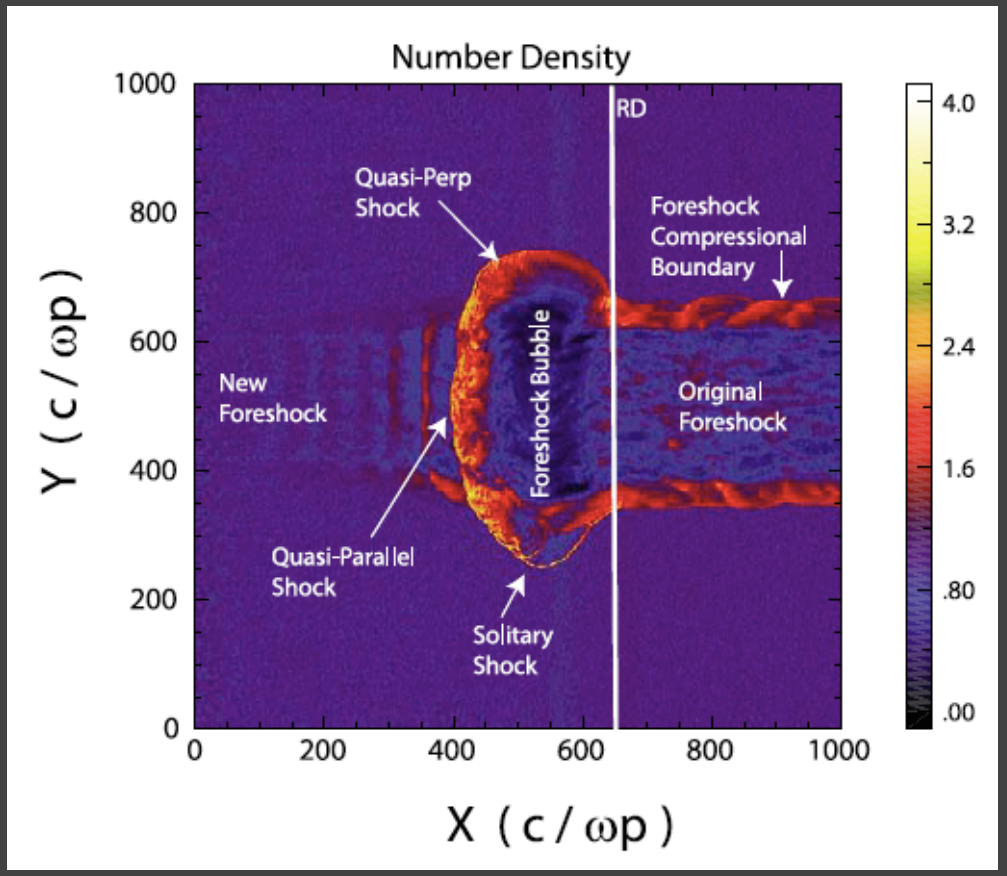


Omidi et al. [JGR 2005]

Foreshock Bubbles

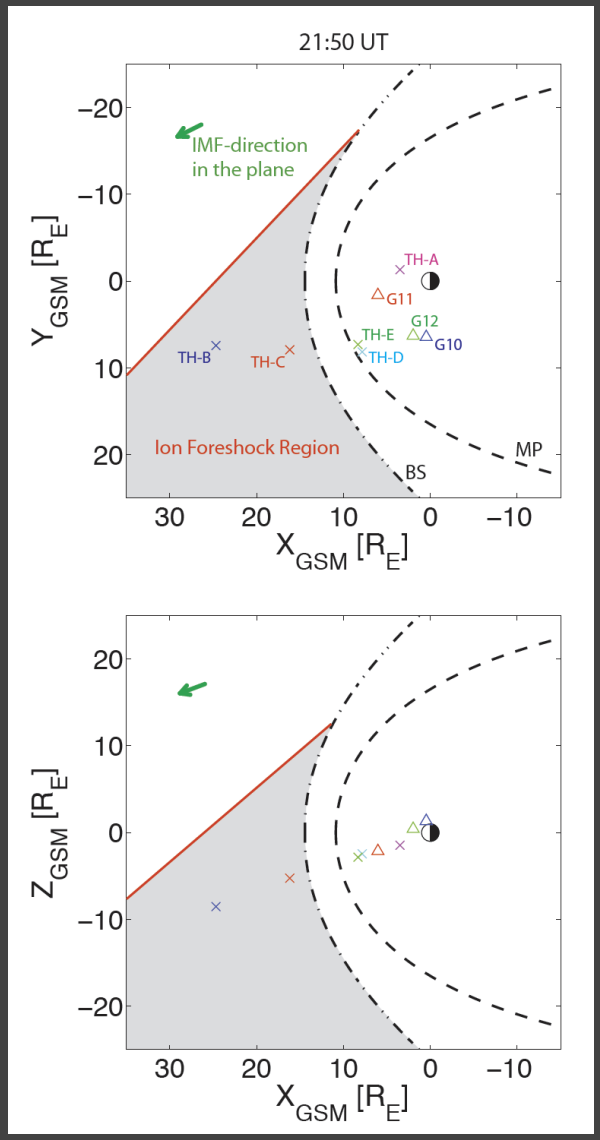
- Recent finding by Omidi et al. [JGR 2010] using 2.5-D hybrid simulations
  - Ions treated kinetically via PIC; electrons as massless fluid
  - 2-D in space; 3-D for currents and fields
- Demonstrated that foreshock "bubbles" can form after a discontinuity in the IMF
- These can then penetrate the sheath and disturb the magnetopause
- ***Foreshock bubbles have not yet been identified in-situ***

Omidi et al. [JGR 2010]



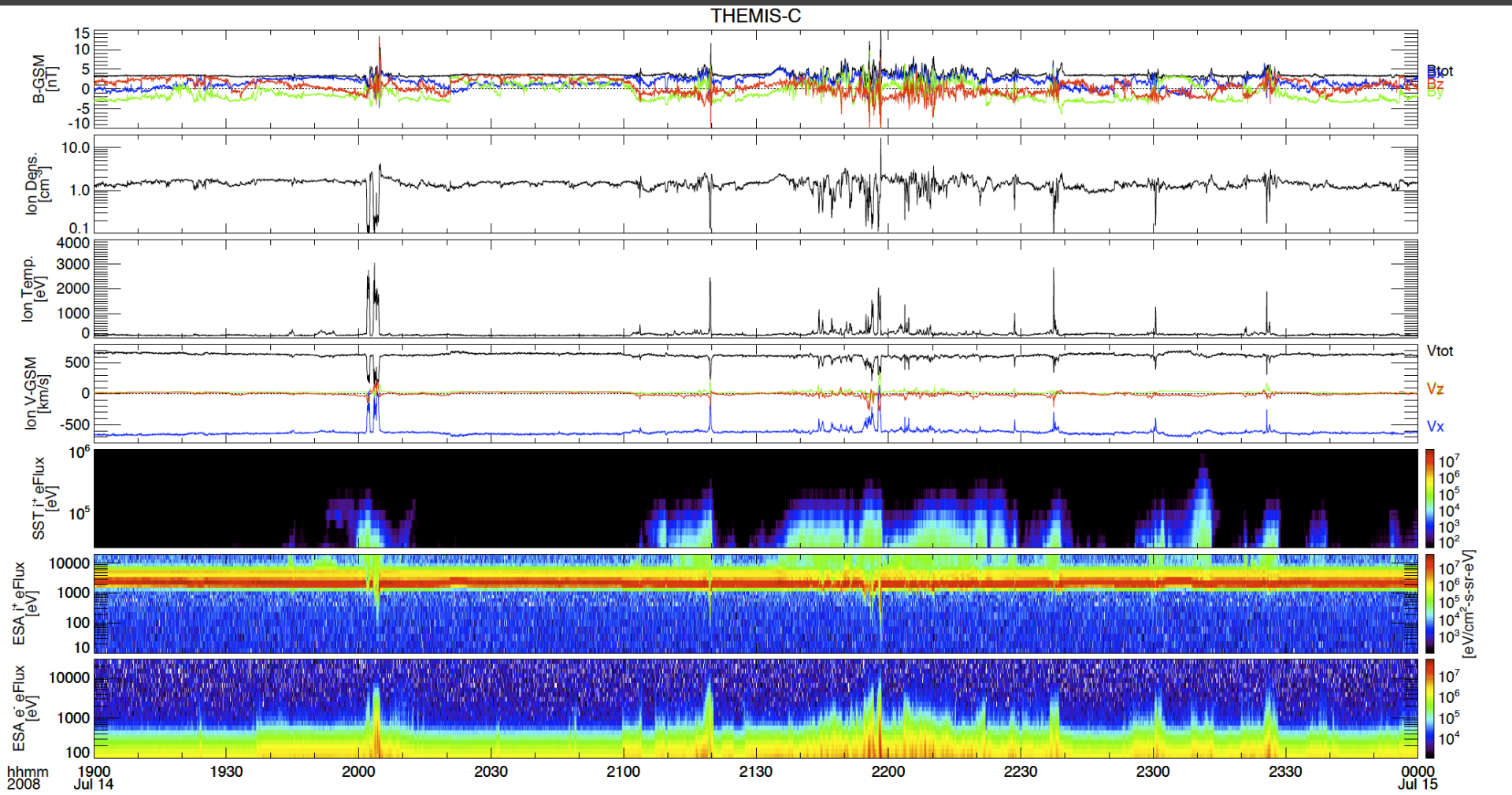
Bastille Day 2008

- THEMIS-B and TH-C in the ion foreshock for much of the last half of the day
- TH-E and -D were near the magnetopause
- Several GOES were also available at GEO
- Several interesting foreshock events were observed, incl. one in particular just before 22:00 UT



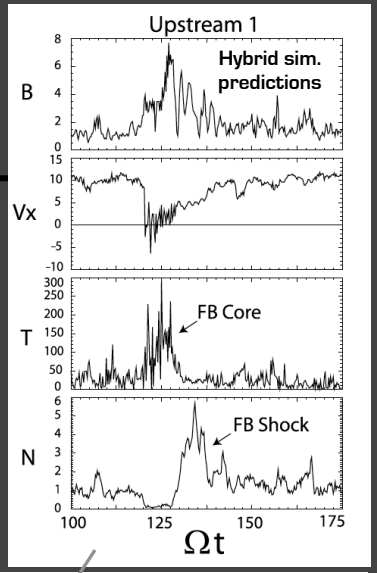
Bastille Day 2008

- Multiple foreshock phenomena observed in a few hours…

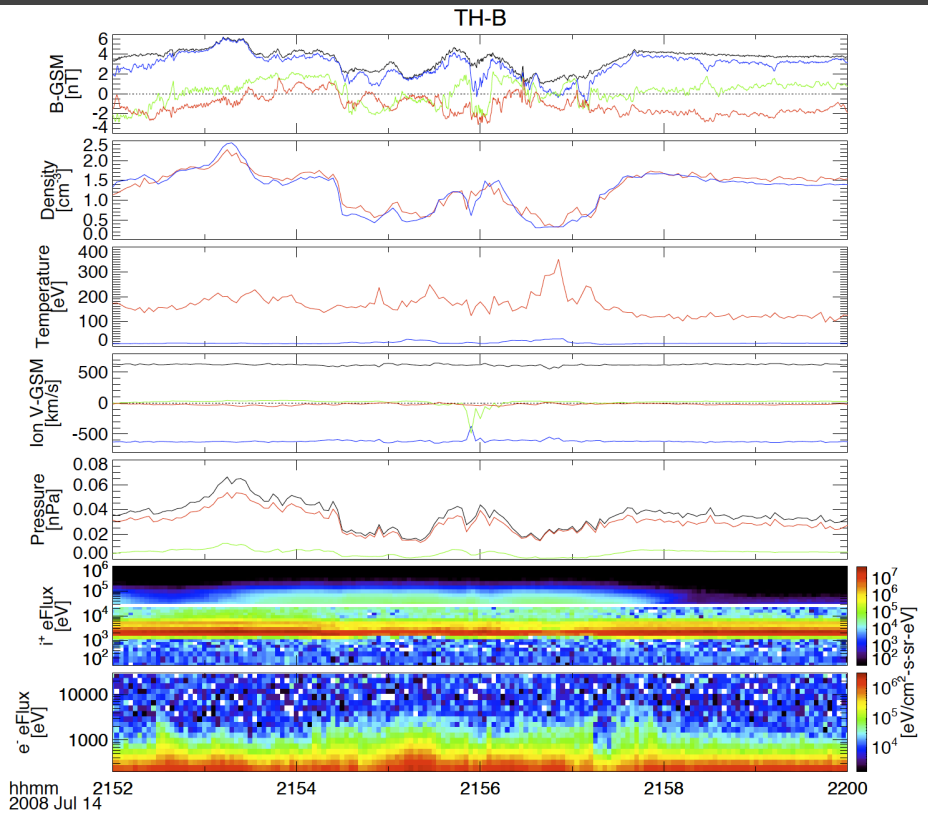


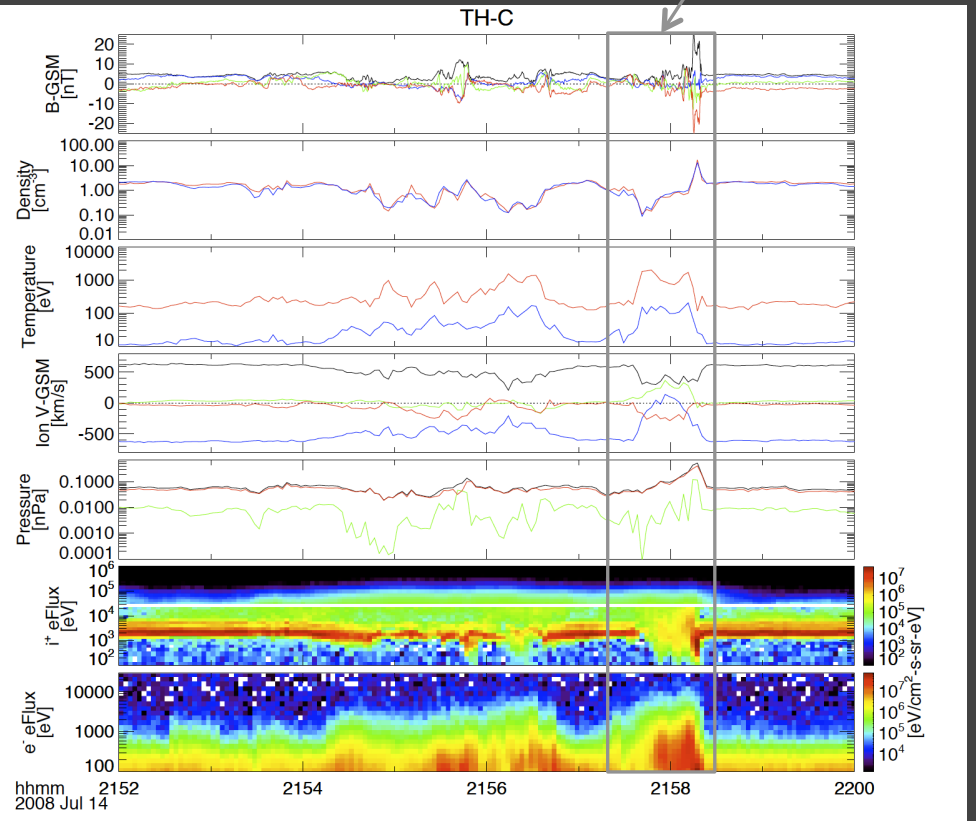
Foreshock Bubbles

Omidi et al. [JGR 2010]



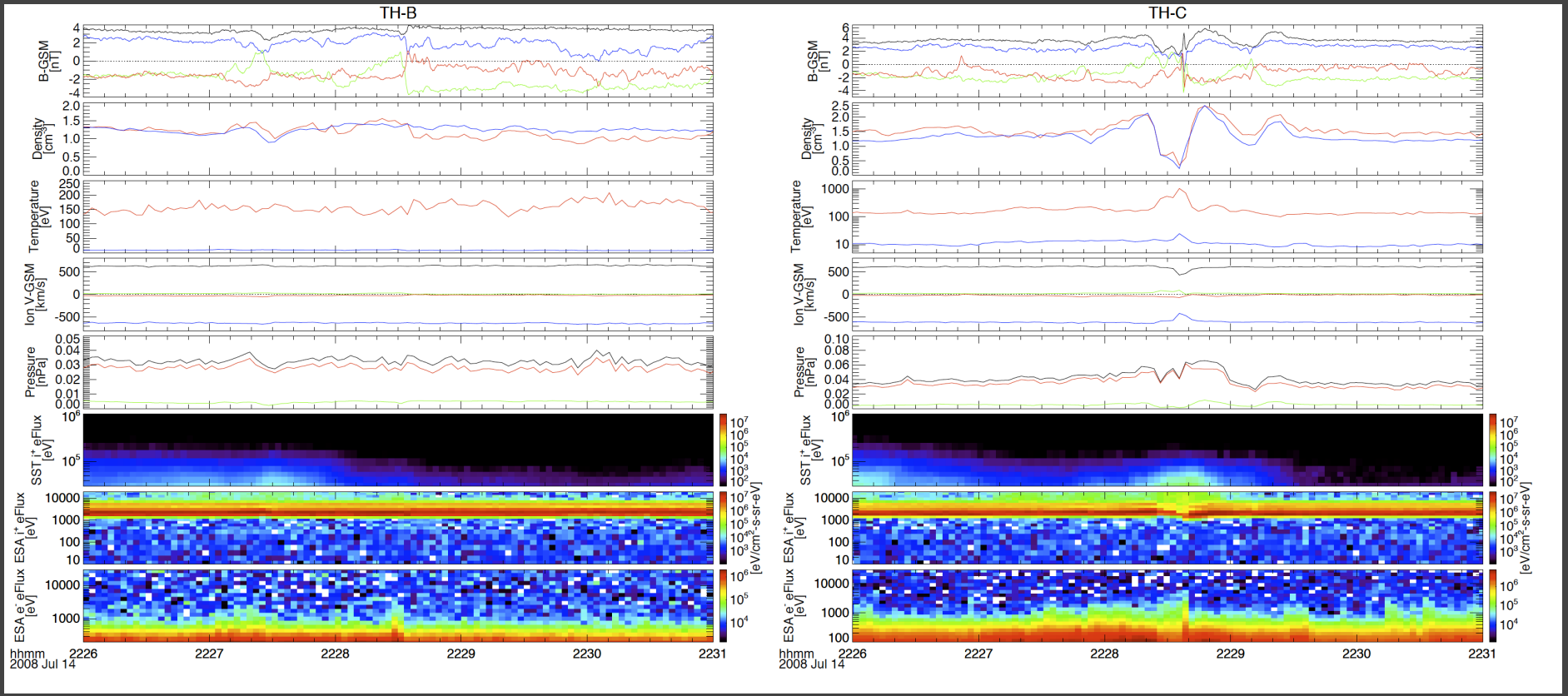
- Features consistent with foreshock bubble simulations and are clearly moving with the solar wind
- Enhanced fluxes of energetic electrons and ions are consistent with additional particle acceleration





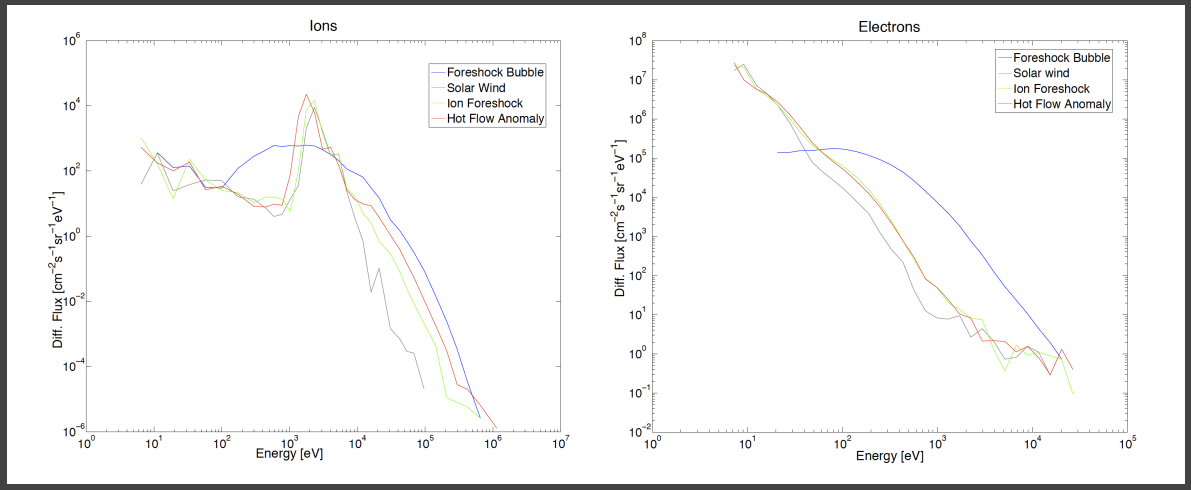
FBs or HFAs?

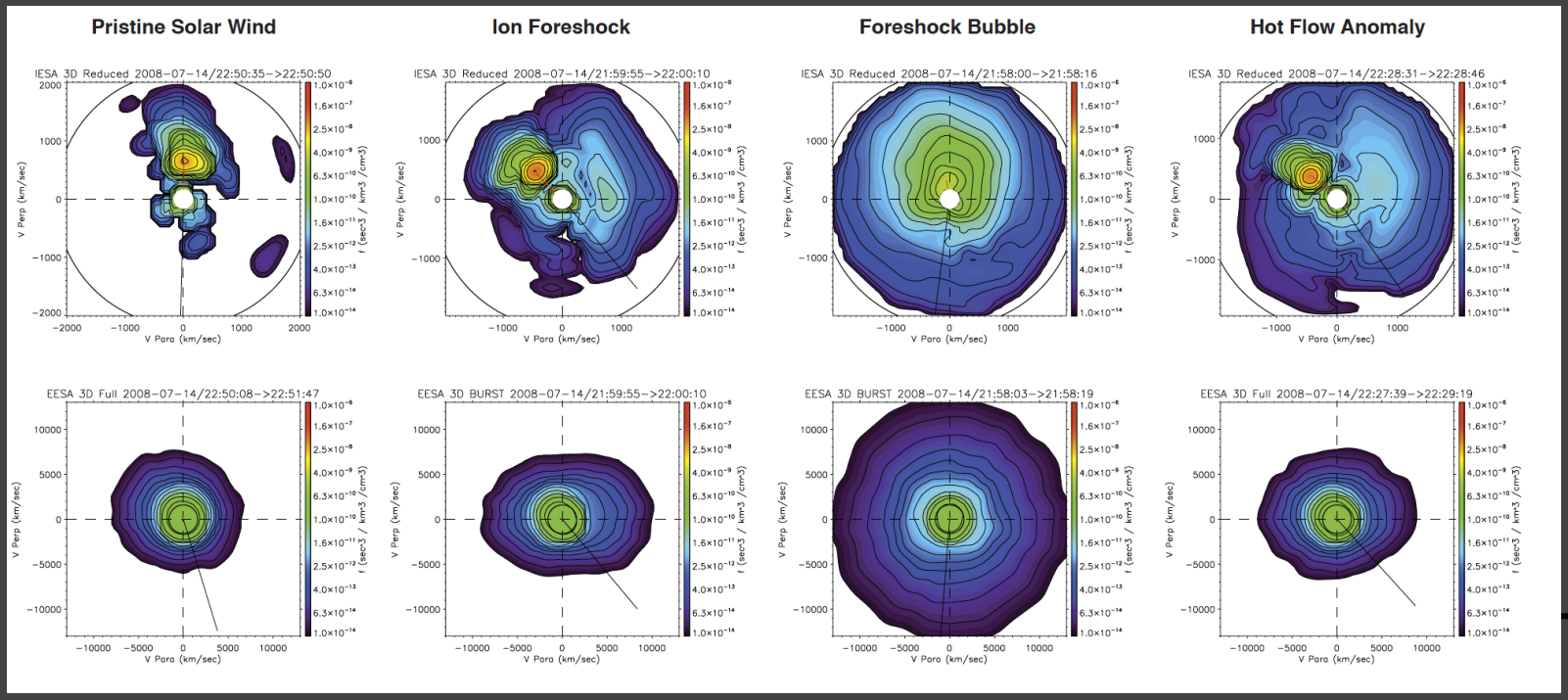
- HFAs shouldn't be observed at TH-B; they are only within ~2 R_E of the bow shock
- HFAs have compression regions on both sides
- HFAs do not convect with the solar wind



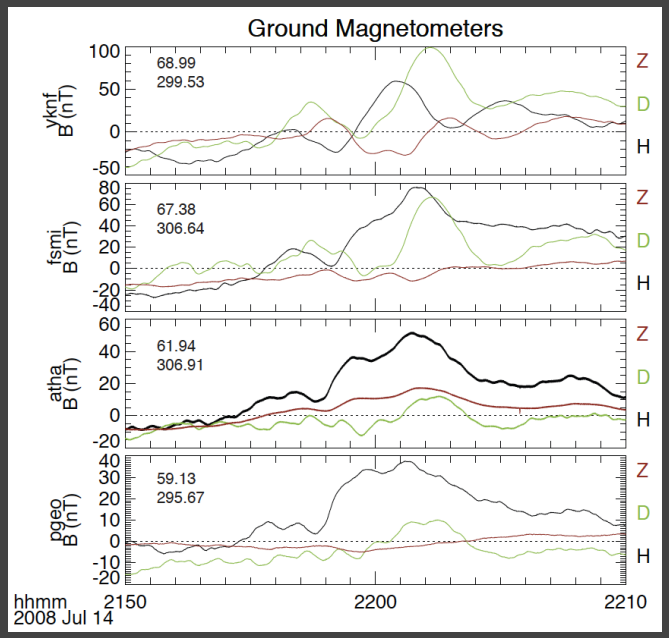
Particle Acceleration

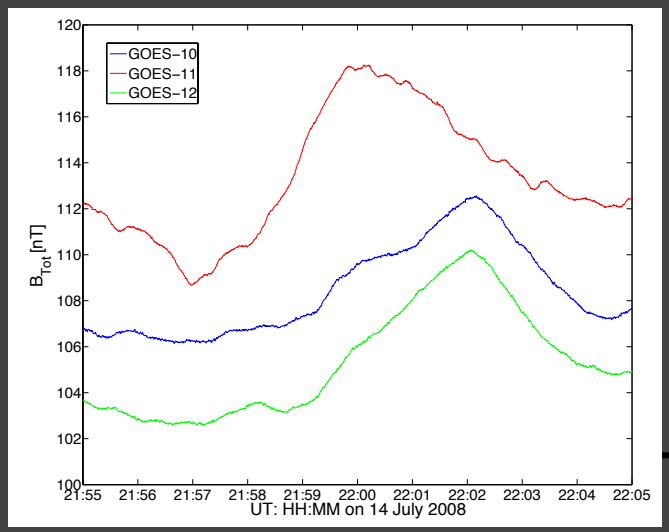
- FBs involve two converging shocks; they are ideal for significant particle acceleration by a combination of 1st and 2nd order Fermi and shock-drift acceleration!



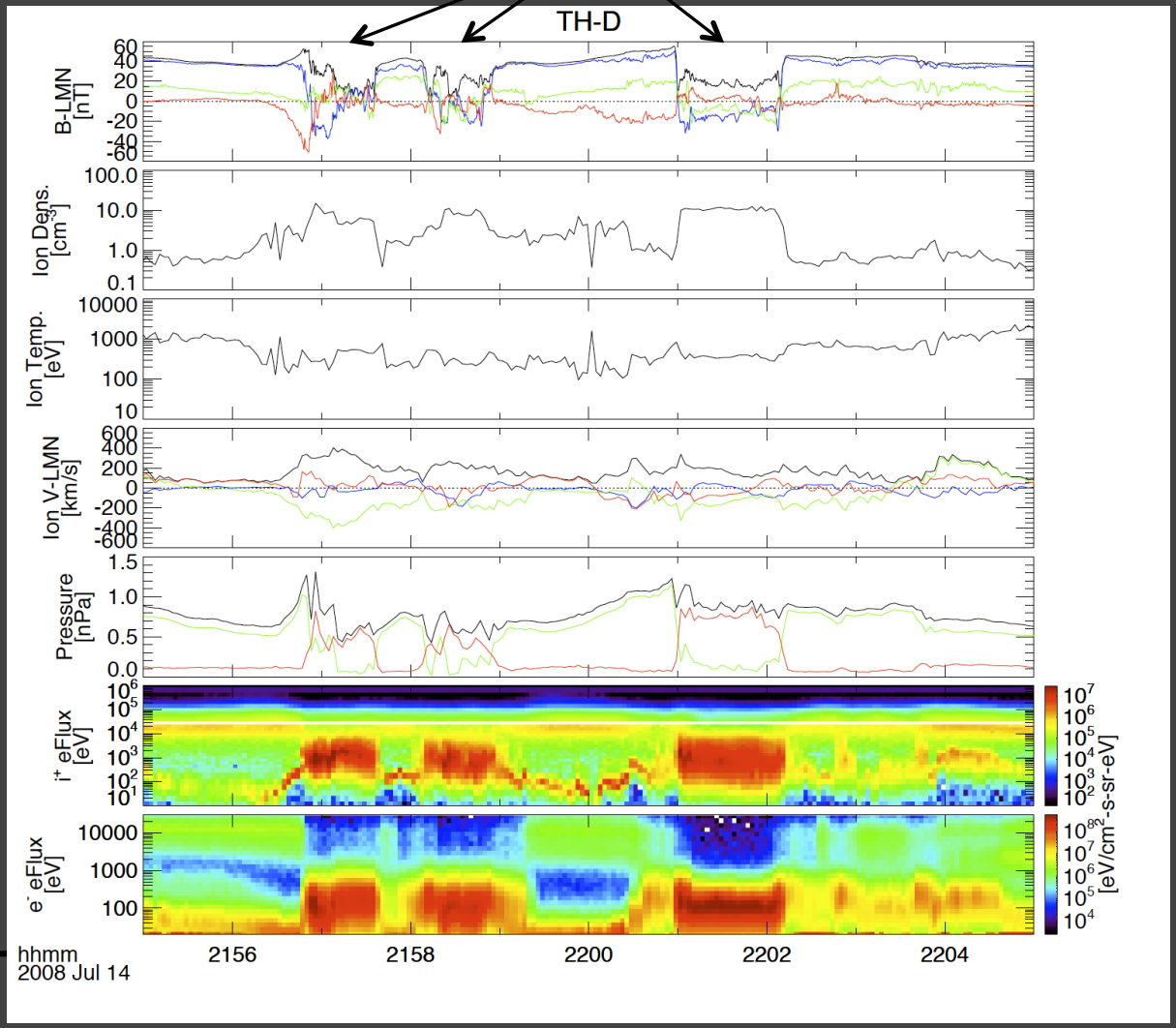


Magnetosphere Effects





3 compressions, consistent with 3 FBs



Conclusions

- ***These are first observations identified as a foreshock bubble, confirming the predictions made by Omidi et al. [2010] based on hybrid simulations***
- Care must be taken ***using multi-point observations to distinguish between HFAs and foreshock bubbles***
- ***Foreshock bubbles should occur regularly***
- Like HFAs, ***foreshock bubbles can have drastic effects on the magnetosphere***
- ***Foreshock bubbles are efficient particle accelerators*** via 1st and 2nd order Fermi and shock drift processes
- ***We plan on conducting further studies to identify more FBs and to compare and contrast HFAs and FBs***